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Furushima

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(54) **SHAPE MEASURING INSTRUMENT,
IMPEDANCE DETECTOR, AND IMPEDANCE
DETECTION METHOD**

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G01B 7/012 (2006.01)
G01R 27/04 (2006.01)

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G01R 27/04 (2013.01)

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G01B 21/04; G01B 21/045; G01R 27/02;
G01R 27/04; G01R 27/16; G01R 31/02;
G01R 31/021
USPC 33/503; 324/527, 539, 542, 543;
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See application file for complete search history.

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(57) **ABSTRACT**

A coordinate measuring device includes a probe detecting a shape of a measured object and outputting a signal indicating results of the shape detection. A probe interface receives the signal indicating the results of the shape detection. A cable transmits the signal indicating the results of the shape detection between the probe and the probe interface and bends accompanying displacement of the probe. The probe interface includes an impedance detector having a calculator detecting impedance in the cable. The impedance detector transmits high-speed test data to the probe through the cable and detects impedance in the cable according to whether a reception confirmation signal output by the probe is received.

25 Claims, 10 Drawing Sheets

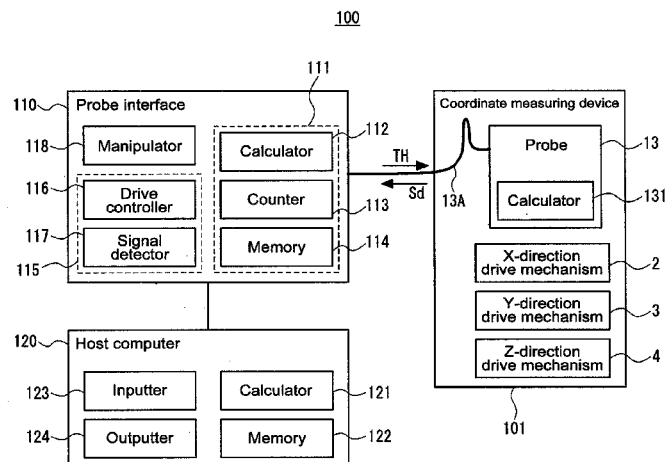


Fig. 1

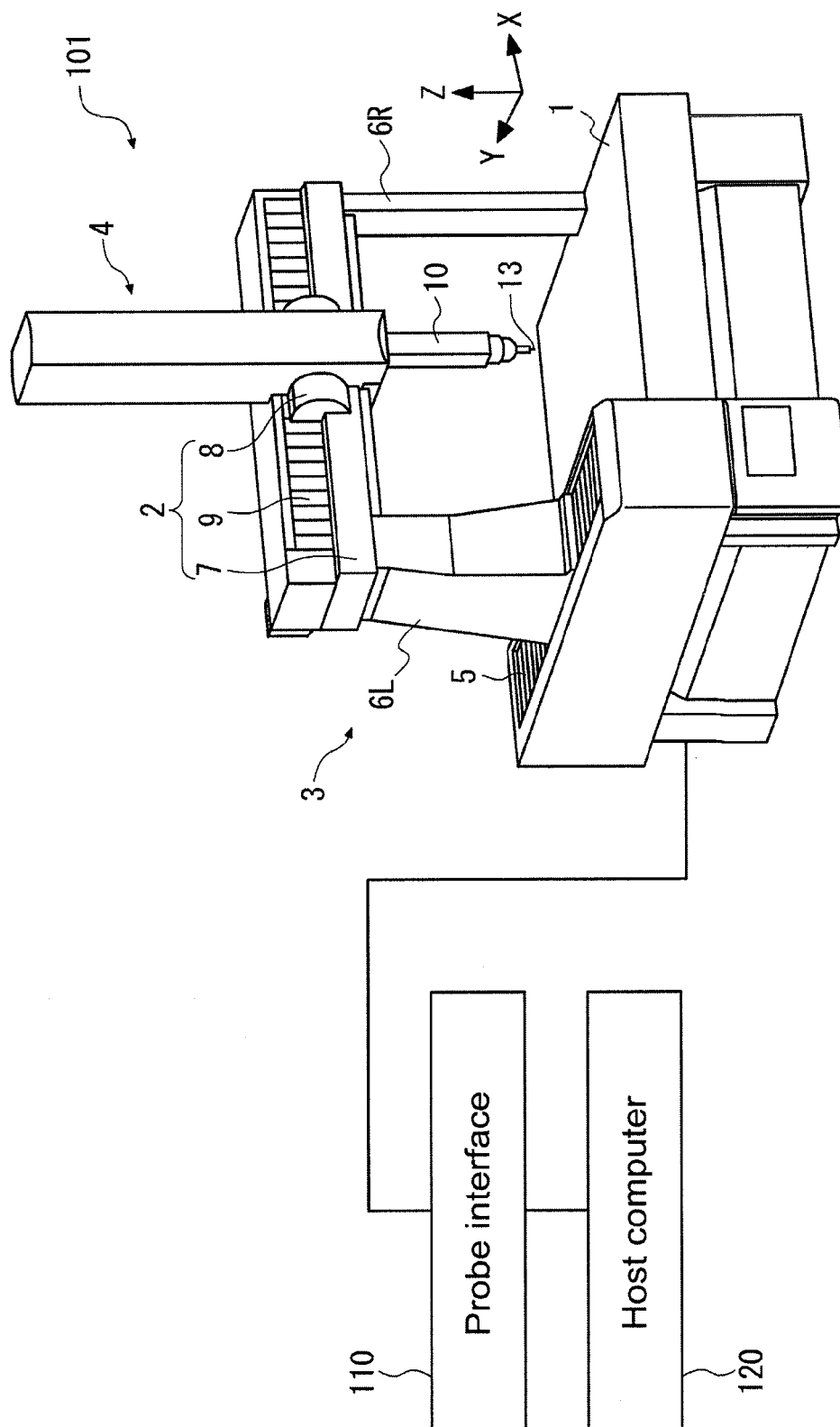
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Fig. 2

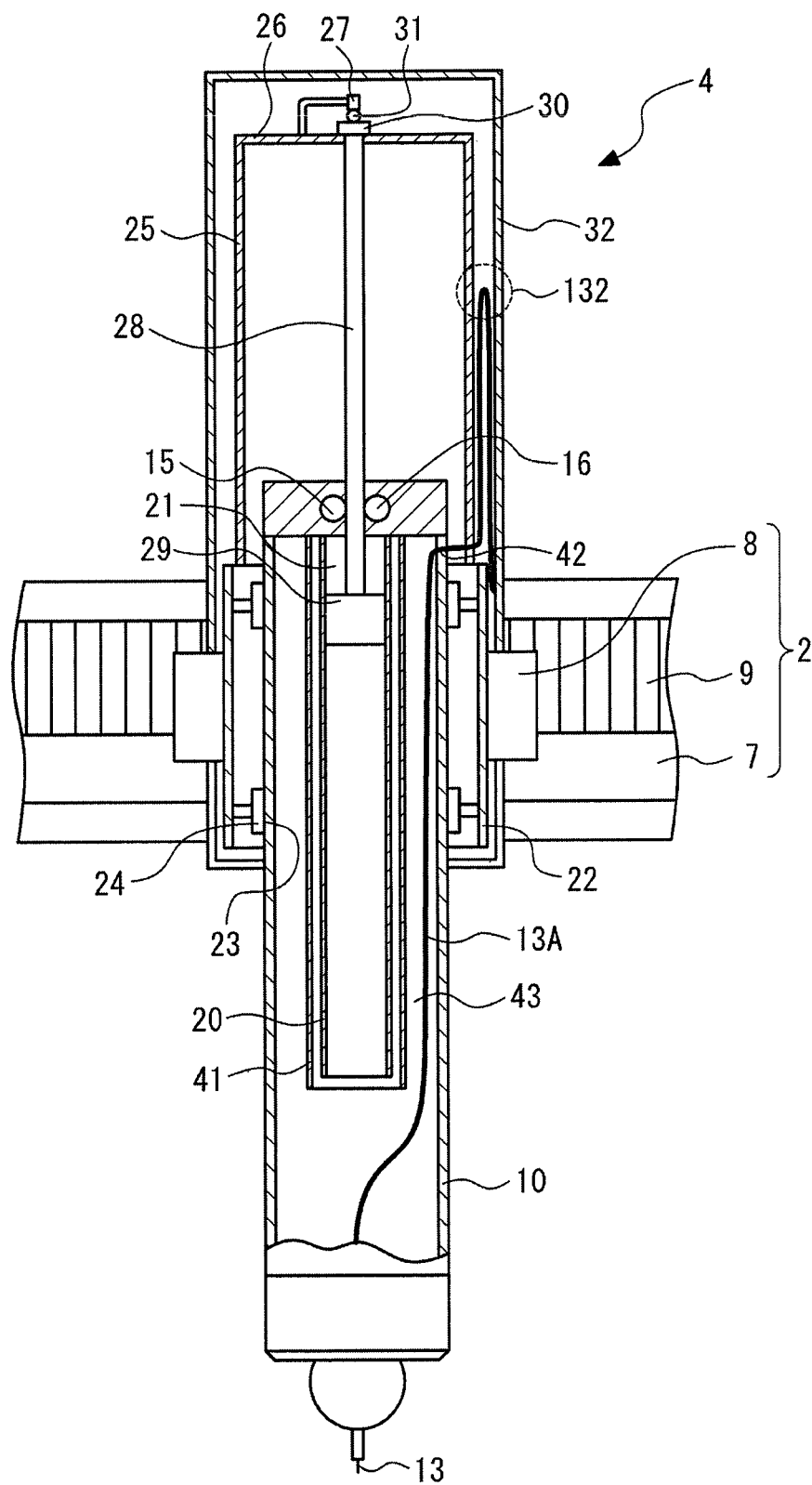


Fig. 3

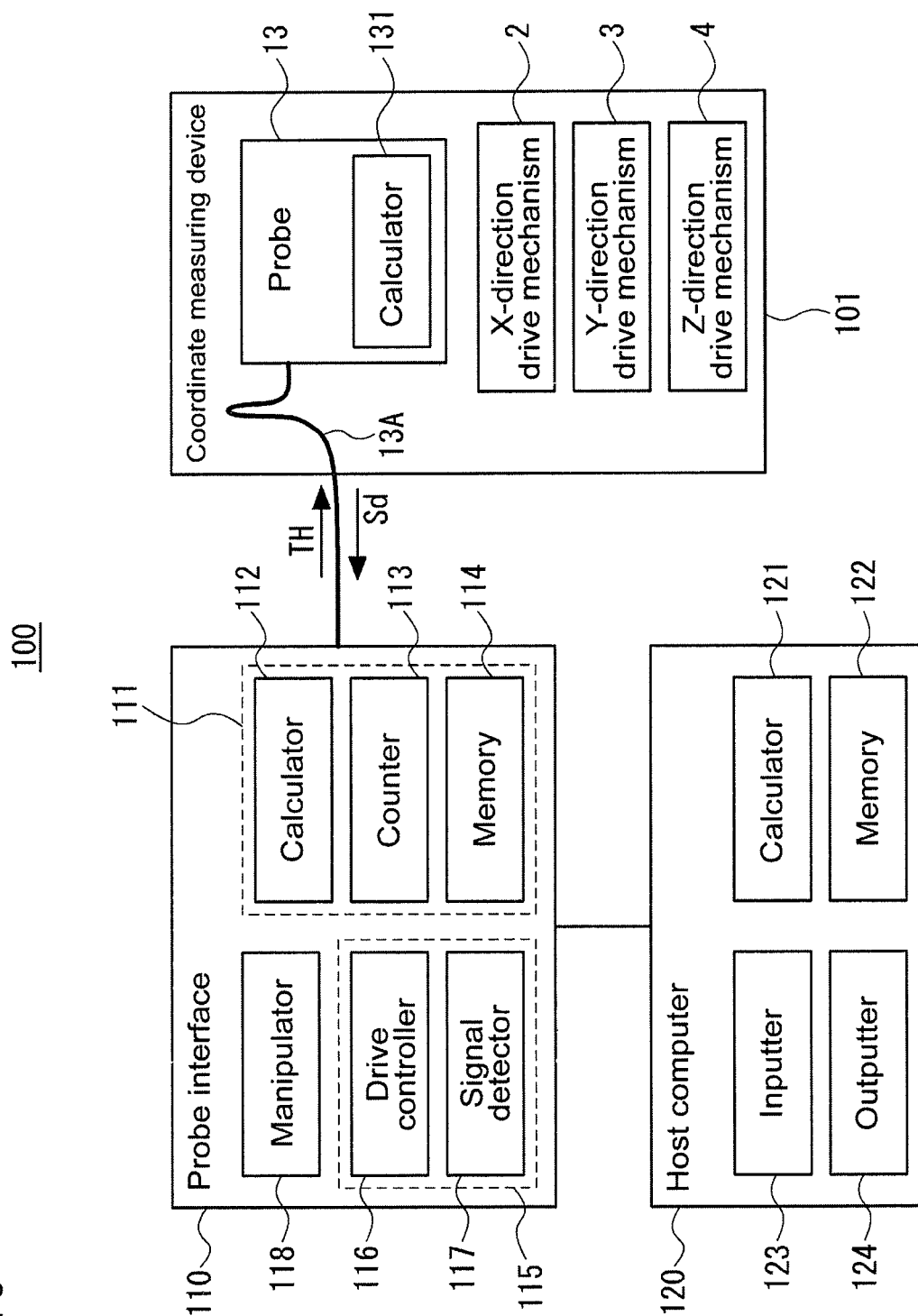


Fig. 4

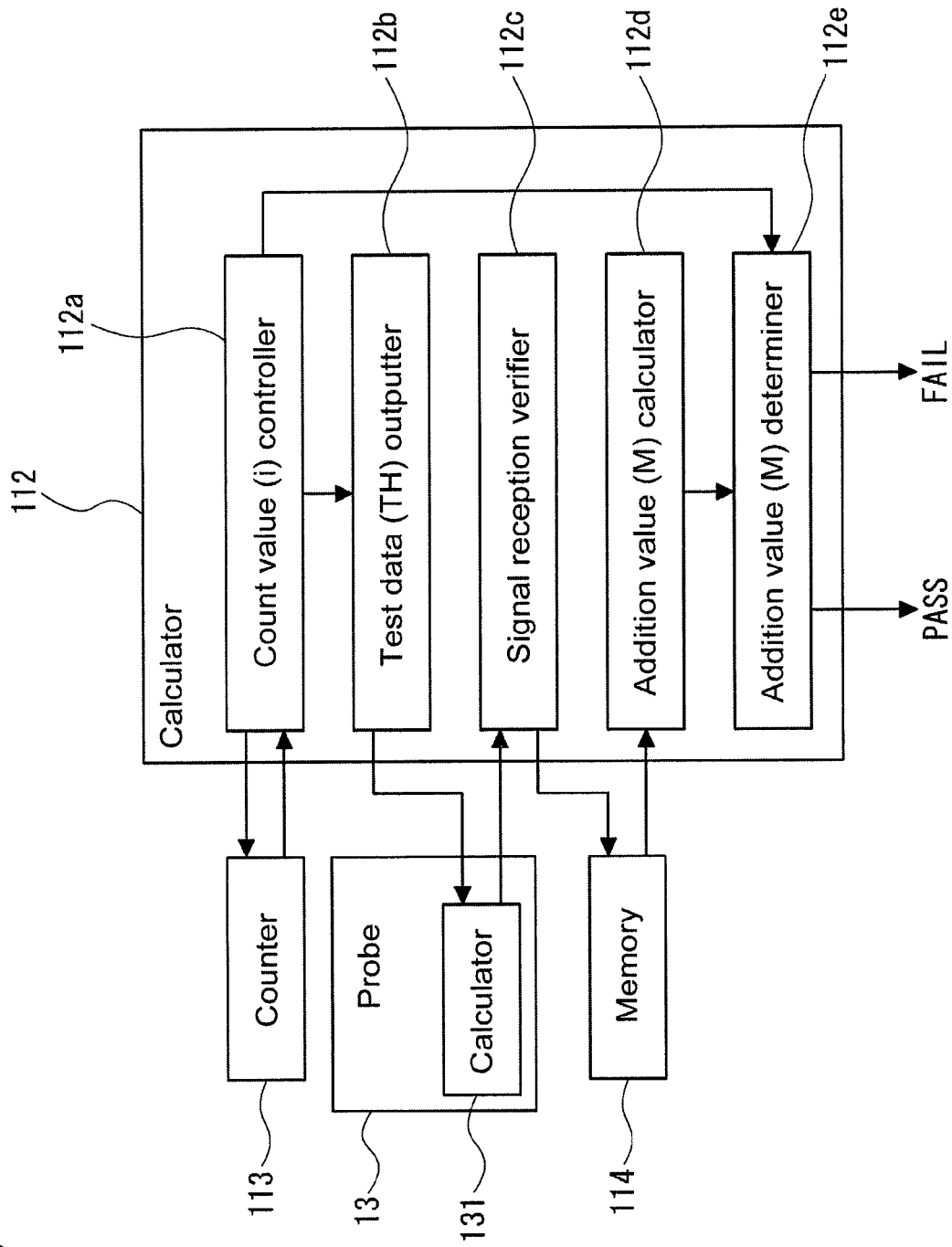


Fig. 5

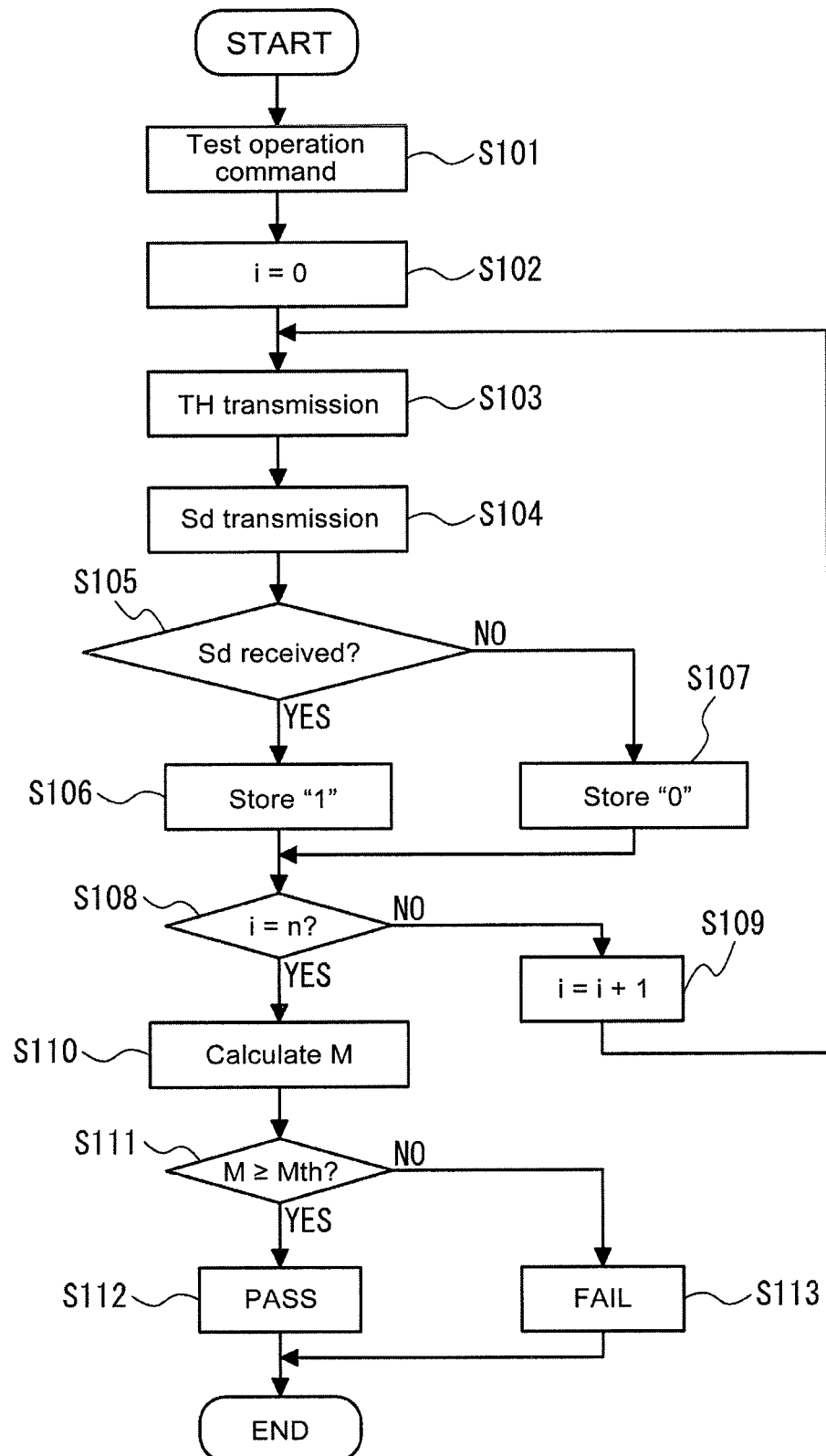


Fig. 6

200

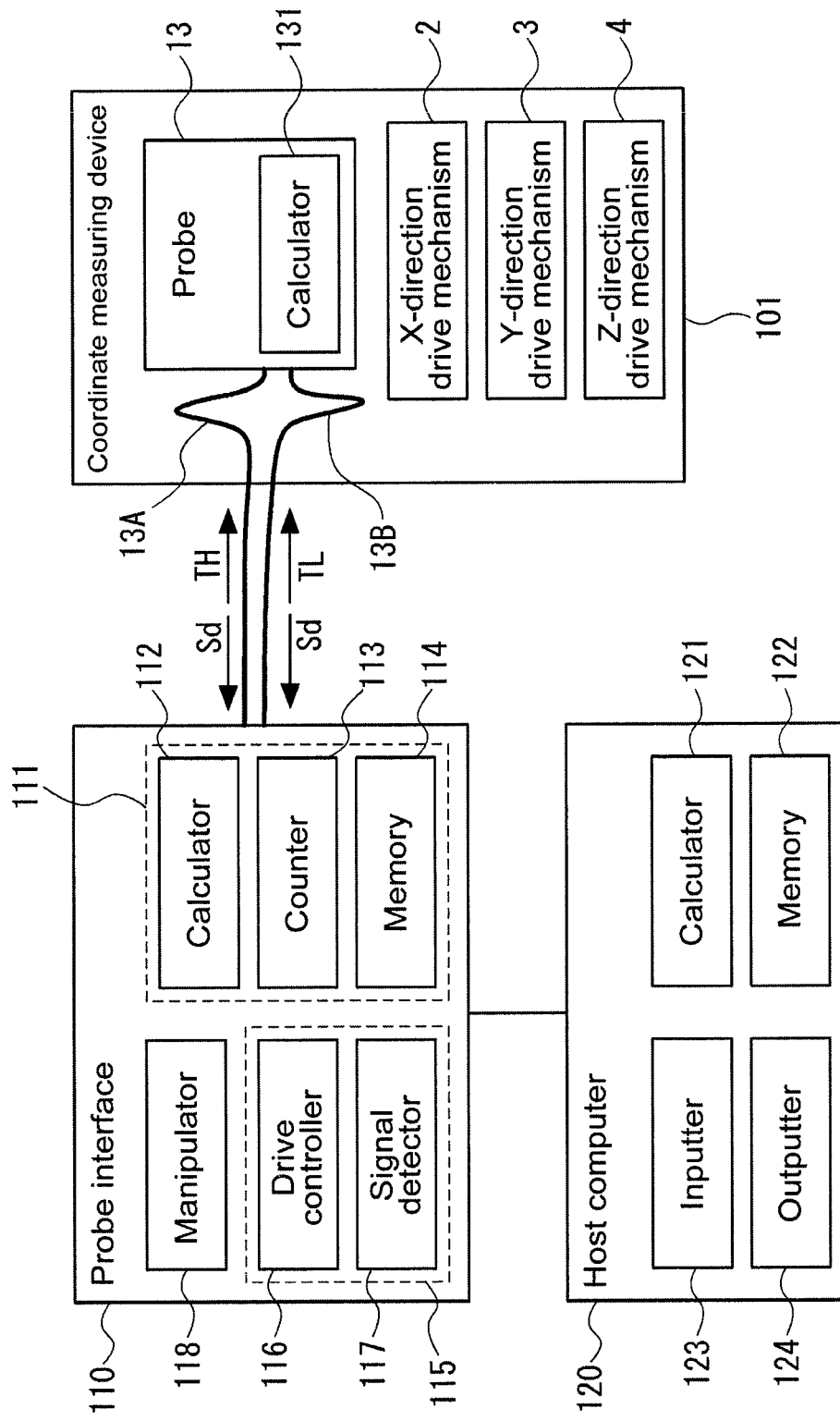


Fig. 7

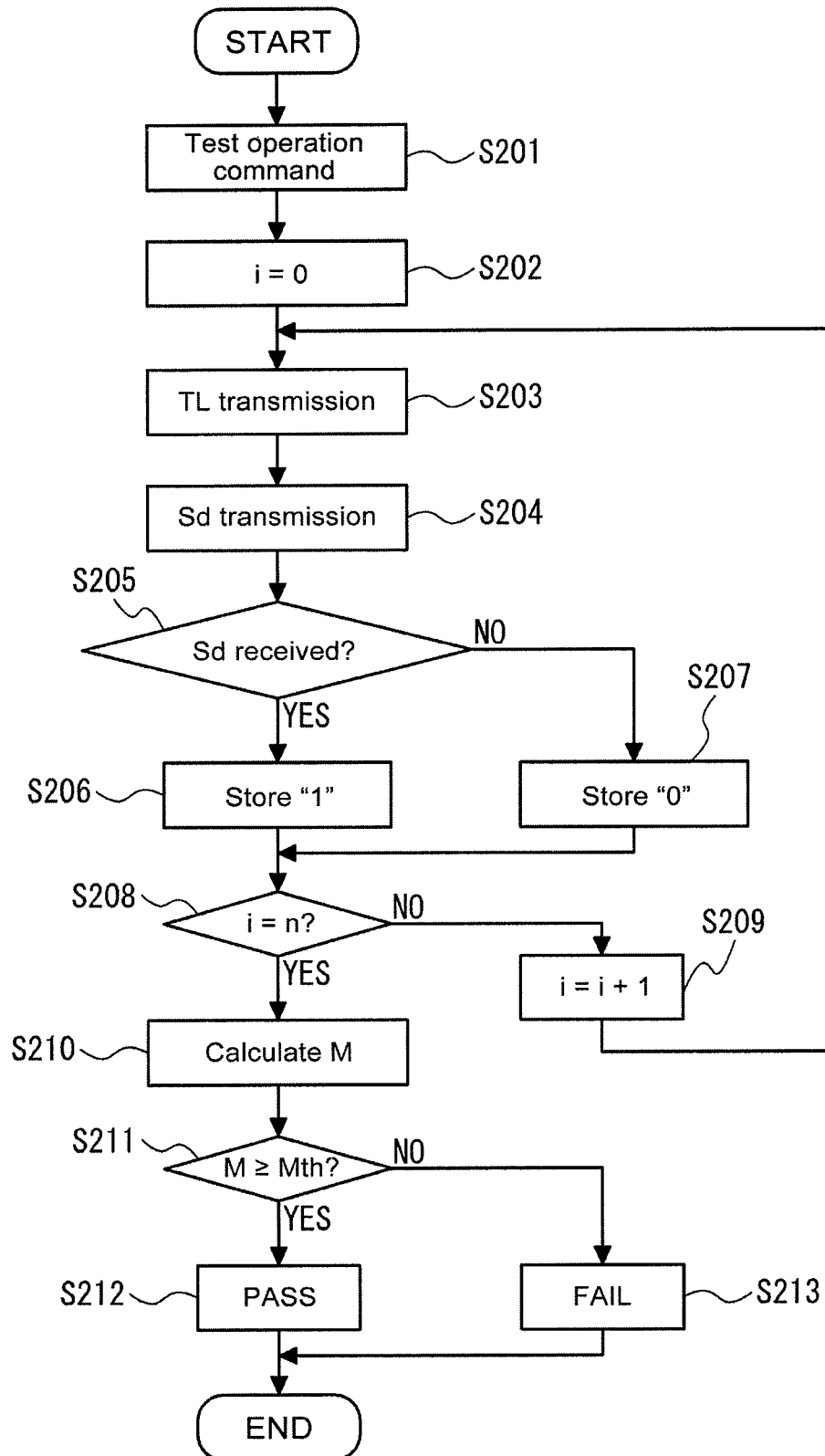


Fig. 8

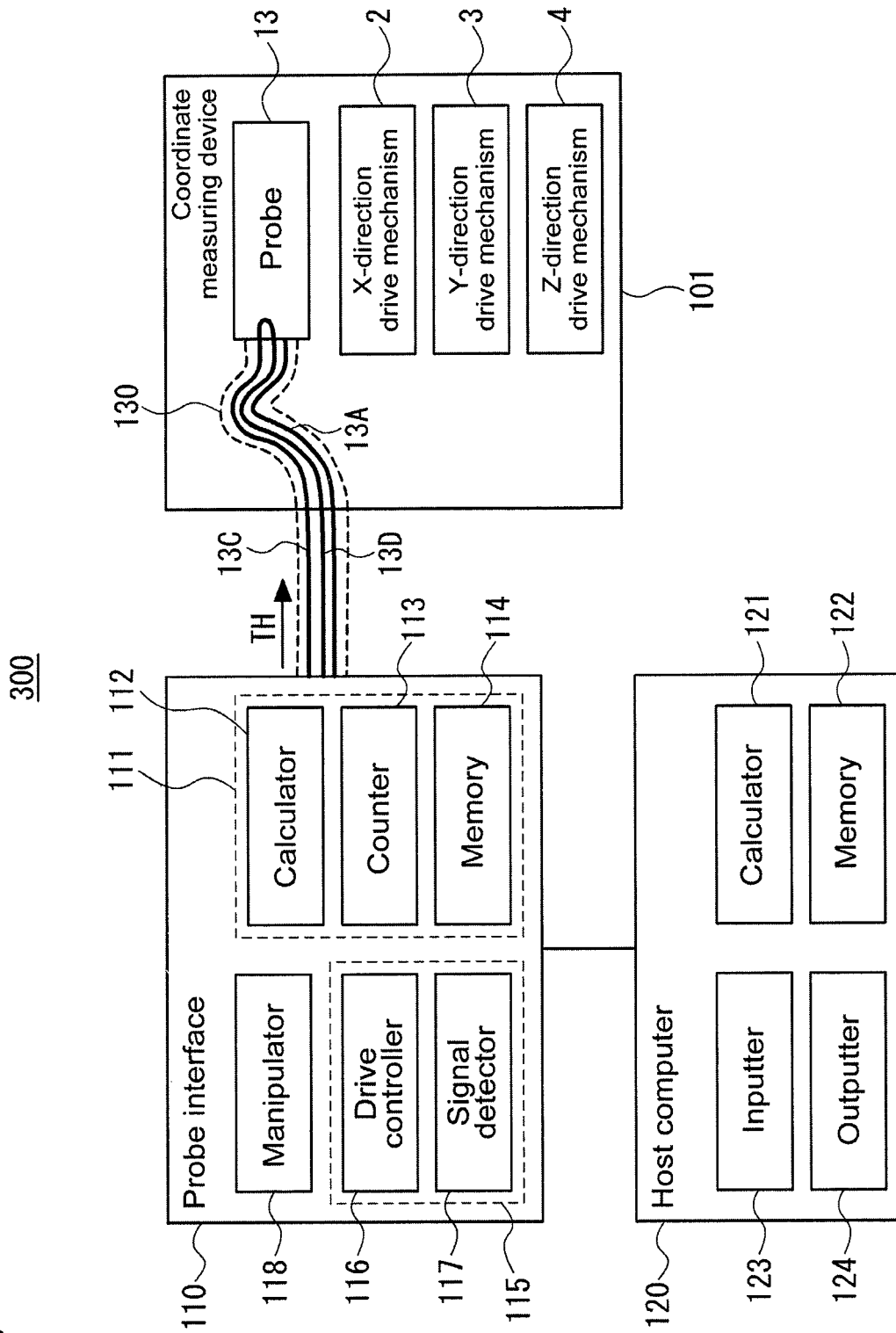


Fig. 9

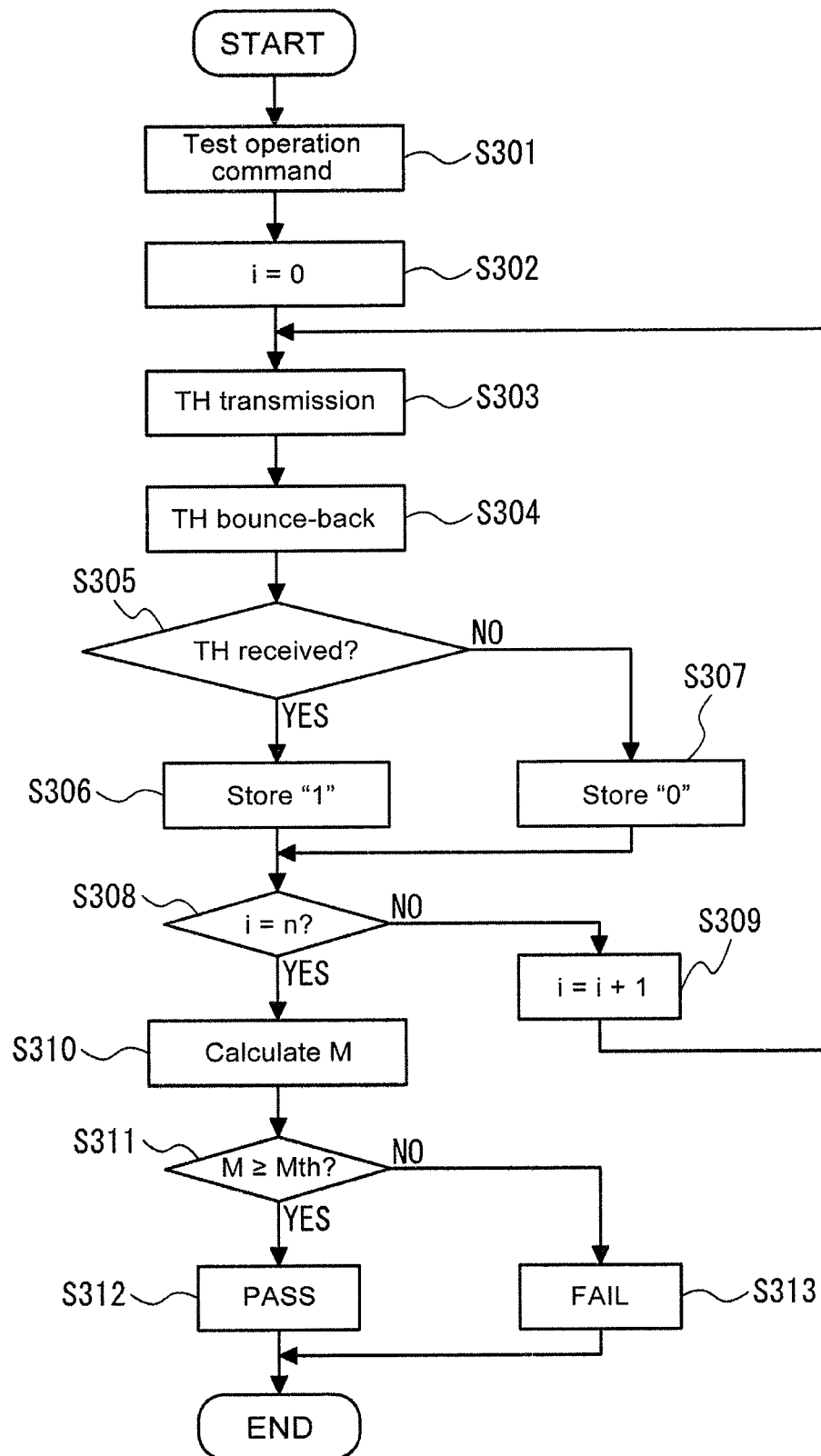
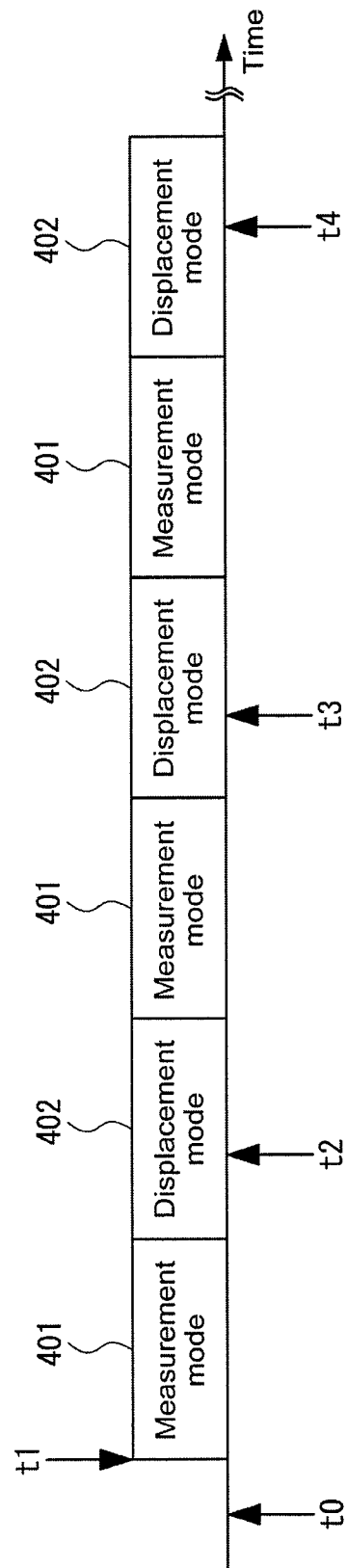


Fig. 10



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SHAPE MEASURING INSTRUMENT, IMPEDANCE DETECTOR, AND IMPEDANCE DETECTION METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application claims priority under 35 U.S.C. §119 of Japanese Application No. 2012-245582, filed on Nov. 7, 2012, the disclosure of which is expressly incorporated by reference herein in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a shape measuring instrument, an impedance detector, and an impedance detection method. For example, the present invention relates to a shape measuring instrument, an impedance detector, and an impedance detection method that detect impedance in a cable having a bent portion and connected to a movable portion.

2. Description of Related Art

Nowadays, in order to test accuracy of processing on a manufactured item having a three-dimensional shape, a shape measurer such as a coordinate measuring device is used. A coordinate measuring device of this kind performs shape measurement by displacing a probe mounted on a non-contact measurer along the three-dimensional shape. When such shape measurement is conducted for a long period of time, impedance increases due to repeatedly bending a cable connected to the probe. The cable is chiefly configured by electric wires made of metal. When metal having a high degree of purity is repeatedly deformed within its range of elastic deformation, no distortion is caused in a metallic crystalline structure thereof. However, in an actual cable, when deformation is repeated a large number of times, even within the range of elastic deformation, distortion gradually accrues, caused by the metallic crystalline structure, which contains impurities. As a result, impedance in the cable increases. For example, in a coordinate measuring device that transfers image data, data transfer becomes impossible due to the increased impedance in the cable.

In order to resolve the above-noted issues, a technique has been suggested in which impedance is reviewed by a signal wire conduction check in a case where a contact measurer is mounted on a probe (Japanese Patent Laid-open Publication No. 2007-333674). The technique discloses performing the impedance review using a dedicated testing tool.

However, the inventor of the present invention has discovered an issue with respect to the above-noted technique. The above-noted technique requires the dedicated testing tool. Therefore, the impedance review cannot be performed readily, which causes costs to increase.

SUMMARY OF THE INVENTION

An aspect of the present invention is a shape measuring instrument including a measuring device (measurer), a control device (controller), and a cable. The measuring device includes a movable detector detecting a shape of a measured object and outputting a signal indicating results of the shape detection. The control device receives the signal indicating the results of the shape detection. The cable transmits the signal indicating the results of the shape detection between the movable detector and the control device and bends accompanying displacement of the movable detector. The control device includes an impedance detector detecting impedance

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in the cable. The impedance detector includes a calculator detecting the impedance in the cable according to whether a reception confirmation signal is received through the cable, the reception confirmation signal being output from the movable detector when test data is transmitted through the cable to the movable detector and the movable detector receives the test data.

Another aspect of the present invention is the shape measuring instrument, wherein the calculator outputs the test data to the movable detector N times (where N is an integer equal to or greater than 1), outputs a pass determination when the reception confirmation signal is received at least M times (where M is an integer equal to or greater than 1 and equal to or less than N), and outputs a fail determination when the reception confirmation signal is received less than M times (where M is an integer equal to or greater than 1 and equal to or less than N).

Another aspect of the present invention is the shape measuring instrument, wherein the impedance detector further includes a counter controlling a number of times the test data output from the calculator is output, and a memory storing information indicating a number of times the reception confirmation signal output from the calculator is received.

Another aspect of the present invention is the shape measuring instrument, wherein the calculator includes a test data outputter outputting the test data to the movable detector; a signal reception verifier confirming whether the reception confirmation signal is received; a count value controller controlling a value defined by the counter; a calculator calculating the number of times the reception confirmation signal is received; and a determiner determining whether the number of times the reception confirmation signal is received is equal to or greater than M based on the information stored in the memory.

Another aspect of the present invention is the shape measuring instrument, wherein a communication speed of the test data transmitted from the control device, through the cable, and to the movable detector is faster than a communication speed of a signal transmitted from the movable detector, through the cable, and to the control device when performing a shape measurement.

Another aspect of the present invention is the shape measuring instrument including a plurality of the cables. The communication speed of the signal indicating the results of the shape detection transmitted from the movable detector, through the plurality of cables, and to the calculator differs for each of the plurality of cables. The communication speed of the test data transmitted from the calculator, through the plurality of cables, and to the movable detector differs for each of the plurality of cables.

Another aspect of the present invention is the shape measuring instrument, wherein the cable is a bundled cable including a first through third cables. The signal indicating the results of the shape detection is transmitted from the movable detector, through the first cable, and to the calculator. The test data is transmitted from the calculator, through the second cable, and to the movable detector. A connection end of the second cable on the movable detector side and a connection end of the third cable on the movable detector side are short-circuited. The test data is transmitted from the movable detector, through the second cable, and to the calculator as the reception confirmation signal. Impedance detection results for the second and third cables are output as impedance results for the first cable.

Another aspect of the present invention is the shape measuring instrument, wherein the calculator detects the imped-

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ance in the first cable before the measuring device begins a shape measurement operation.

Another aspect of the present invention is the shape measuring instrument, wherein the calculator detects the impedance in the cables after the measuring device begins the shape measurement operation, during a time when the movable detector is displaced from a first measurement position to a second measurement position without performing shape measurement.

Another aspect of the present invention is an impedance detector including a calculator. The calculator outputs test data through a cable to a movable portion of an instrument having the movable portion, the movable portion outputting a signal indicating results of an operation and the cable being bent accompanying displacement of the movable portion. The calculator detects impedance in the cable according to whether a reception confirmation signal output when the movable portion receives the test data is confirmed to be received through the cable.

Another aspect of the present invention is the impedance detector, wherein the calculator outputs the test data to the movable portion N times (where N is an integer equal to or greater than 1), outputs a pass determination when the reception confirmation signal is received at least M times (where M is an integer equal to or greater than 1 and equal to or less than N), and outputs a fail determination when the reception confirmation signal is received less than M times (where M is an integer equal to or greater than 1 and equal to or less than N).

Another aspect of the present invention is the impedance detector, wherein the impedance detector further includes a counter controlling a number of times the test data output from the calculator is output, and a memory storing information indicating a number of times the reception confirmation signal output from the calculator is received.

Another aspect of the present invention is the impedance detector, wherein the calculator includes a test data outputter outputting the test data to the movable portion; a signal reception verifier confirming whether the reception confirmation signal is received; a count value controller controlling a value defined by the counter; a calculator calculating a number of times the reception confirmation signal is received; and a determiner determining whether the number of times the reception confirmation signal is received is equal to or greater than M based on the information stored in the memory.

Another aspect of the present invention is the impedance detector, wherein a communication speed of the test data transmitted from the calculator, through the cable, and to the movable portion is faster than a communication speed of the signal indicating the results of the operation and transmitted from the movable portion, through the cable, and to the control device of the instrument having the movable portion.

Another aspect of the present invention is the impedance detector including a plurality of the cables. The communication speed of the signal indicating the results of the operation and transmitted from the movable portion, through the plurality of cables, and to the control device of the instrument having the movable portion differs for each of the plurality of cables. The communication speed of the test data transmitted from the control device, through the plurality of cables, and to the movable portion differs for each of the plurality of cables.

Another aspect of the present invention is the impedance detector, wherein the cable is a bundled cable including a first through third cables. The signal indicating results of shape detection is transmitted from the movable portion, through the first cable, and to the calculator. The test data is transmitted from the calculator, through the second cable, and to the movable portion. A connection end of the second cable on the

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movable portion side and a connection end of the third cable on the movable portion side are short-circuited. The test data is transmitted from the movable portion, through the second cable, and to the calculator as the reception confirmation signal. Impedance detection results for the second and third cables are output as impedance results for the first cable.

Another aspect of the present invention is the impedance detector, wherein the calculator detects the impedance in the cables before the movable portion begins an operation outputting the signal indicating results of an operation.

Another aspect of the present invention is the impedance detector, wherein the calculator detects the impedance in the cables after the movable portion begins the operation outputting the signal indicating the results of the operation, during a time when the movable portion is displaced from a first measurement position to a second measurement position without outputting the signal indicating the results of the operation.

Another aspect of the present invention is an impedance detection method that includes outputting test data through a cable to a movable portion of an instrument having the movable portion, the movable portion outputting a signal indicating results of an operation and the cable being bent accompanying displacement of the movable portion; confirming whether a reception confirmation signal is received, the signal being output when the movable portion receives the test data is confirmed; and detecting impedance in the cable according to a result of the confirmation.

Another aspect of the present invention is the impedance detection method that includes outputting the test data to the movable portion N times (where N is an integer equal to or greater than 1); outputting a pass determination when the reception confirmation signal is received at least M times (where M is an integer equal to or greater than 1 and equal to or less than N); and outputting a fail determination when the reception confirmation signal is received less than M times (where M is an integer equal to or greater than 1 and equal to or less than N).

Another aspect of the present invention is the impedance detection method, wherein a communication speed of the test data transmitted through the cable to the movable portion is faster than a communication speed of the signal indicating results of an operation and transmitted from the movable portion through the cable.

Another aspect of the present invention is the impedance detection method, wherein the communication speed of the signal indicating the results of the operation and transmitted from the movable portion through a plurality of the cables differs for each of the plurality of cables. The communication speed of the test data transmitted through the plurality of cables to the movable portion differs for each of the plurality of cables.

Another aspect of the present invention is the impedance detection method, wherein the cable is a bundled cable including a first through third cables. The signal indicating results of shape detection is transmitted from the movable portion through the first cable. The test data is transmitted through the second cable to the movable portion. A connection end of the second cable on the movable portion side and a connection end of the third cable on the movable portion side are short-circuited. The test data is transmitted from the movable portion through the second cable as the reception confirmation signal. Impedance detection results for the second and third cables are output as impedance results for the first cable.

Another aspect of the present invention is the impedance detection method, wherein the impedance in the cables is

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detected before the movable portion begins an operation outputting the signal indicating the results of the operation.

Another aspect of the present invention is the impedance detection method, wherein the impedance in the cables is detected after the movable portion begins the operation outputting the signal indicating the results of the operation, during a time when the movable portion is displaced from a first measurement position to a second measurement position without outputting the signal indicating the results of the operation.

According to the present invention, impedance can be readily detected in a cable connected to a movable portion and having a bent portion.

The present invention is clarified by the following detailed description and the appended drawings. The appended drawings are referenced only to facilitate understanding and do not serve to limit the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is further described in the detailed description which follows, in reference to the noted plurality of drawings by way of non-limiting examples of exemplary embodiments of the present invention, in which like reference numerals represent similar parts throughout the several views of the drawings, and wherein:

FIG. 1 is a perspective view schematically illustrating a configuration of a shape measuring instrument **100** according to Embodiment 1;

FIG. 2 is a cross-sectional view schematically illustrating a configuration of a Z-direction drive mechanism **4**;

FIG. 3 is a block diagram schematically illustrating the configuration of the shape measuring instrument **100** according to Embodiment 1;

FIG. 4 is a block diagram schematically illustrating a configuration of a calculator **112**;

FIG. 5 is a flow chart illustrating a test operation for impedance in a cable of the shape measuring instrument **100** according to Embodiment 1;

FIG. 6 is a block diagram schematically illustrating a configuration of a shape measuring instrument **200** according to Embodiment 2;

FIG. 7 is a flow chart illustrating a test operation for impedance in a cable **13B** of the shape measuring instrument **200** according to Embodiment 2;

FIG. 8 is a block diagram schematically illustrating a configuration of a shape measuring instrument **300** according to Embodiment 3;

FIG. 9 is a flow chart illustrating a test operation for impedance in cables of the shape measuring instrument **300** according to Embodiment 3; and

FIG. 10 illustrates an operation mode of a shape measuring instrument **400** according to Embodiment 4 during shape measurement.

DETAILED DESCRIPTION OF THE INVENTION

The particulars shown herein are by way of example and for purposes of illustrative discussion of the embodiments of the present invention only and are presented in the cause of providing what is believed to be the most useful and readily understood description of the principles and conceptual aspects of the present invention. In this regard, no attempt is made to show structural details of the present invention in more detail than is necessary for the fundamental understanding of the present invention, the description taken with the

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drawings making apparent to those skilled in the art how the forms of the present invention may be embodied in practice.

Hereafter, embodiments of the present invention are described with reference to the drawings. Identical reference numerals are assigned to identical elements in each of the plurality of drawings, and thus duplicative descriptions are omitted where necessary.

Embodiment 1

First, a description is given of a shape measuring instrument **100** according to Embodiment 1. FIG. 1 schematically illustrates a configuration of the shape measuring instrument **100** according to Embodiment 1. The shape measuring instrument **100** includes a coordinate measuring device **101**, a probe interface **110**, and a host computer **120**. Hereafter, the probe interface **110** is also referred to as a control device. The coordinate measuring device is also referred to simply as a measuring device.

The coordinate measuring device **101** includes a displacement mechanism provided on a table **1**, the displacement mechanism displacing a probe **13**. A work piece is placed on the table **1**. Hereafter, the probe **13** is also referred to as a movable detector or as a movable portion. The displacement mechanism is configured by an X-direction drive mechanism **2**, a Y-direction drive mechanism **3**, and a Z-direction drive mechanism **4**. The X-direction drive mechanism **2** displaces the probe **13** in an X direction. The Y-direction drive mechanism **3** displaces the probe **13** in a Y direction. The Z-direction drive mechanism **4** displaces the probe **13** in a Z direction.

The table **1** has a quadrangular pillar shape and includes a top surface processed to precision flatness for the purpose of placing the work piece thereon. For purposes of description, two mutually orthogonal directions on the top surface of the table **1** are designated as the X direction (left-right direction) and the Y direction (front-back direction), respectively. In addition, a direction perpendicular to the top surface of the table **1** is designated as the Z direction (vertical direction).

The X-direction drive mechanism **2** is configured with an X beam **7**, an X slider **8**, and an X slider driver **9**. The X beam **7** is a rectangular guide member supported at two ends by a Y slider **6L** and a Y slider **6R**. The X beam **7** is driven by the Y-direction drive mechanism **3** to move in the Y direction. The X slider **8** is a movable member provided so as to be capable of displacing along a longitudinal direction of the X beam **7**. The X slider driver **9** displaces the X slider **8**. An air bearing is provided between the X slider **8** and the X beam **7**; however, a detailed description thereof is omitted.

The Y-direction drive mechanism **3** is configured by a Y guide rail **5**, the Y slider **6L**, and the Y slider **6R**. The Y guide rail **5** is provided on the table **1** in the Y direction. The Y slider **6L** is provided so as to be capable of displacing along the Y guide rail **5**. The Y slider **6R** is paired with the Y slider **6L** and displaces above the table **1** in the Y direction. Air bearings are provided between the Y guide rail **5** and the Y slider **6L**, as well as between the table **1** and the Y slider **6R**; however, a detailed description thereof is omitted.

The coordinate measuring device **101** is connected to the probe interface **110**. In response to a command from the host computer **120**, the probe interface **110** controls operations of the coordinate measuring device **101** and performs shape measurement by detecting a signal from the probe **13**.

FIG. 2 is a cross-sectional view schematically illustrating a configuration of the Z-direction drive mechanism **4**. A Z-axis spindle **10** has an interior formed in a hollow, squared tube shape and is guided in the perpendicular direction by a guide tube **22**. A bottom end of the Z-axis spindle **10** includes the

probe 13 for contacting the work piece and measuring at least one of a position and coordinates of the work piece. The guide tube 22 is provided on the X slider 8 oriented such that a tube opening faces the perpendicular direction. The Z-axis spindle 10 is inserted into an interior of the guide tube 22 so as to be capable of raising and lowering in the vertical direction. In addition, the guide tube 22 supports the Z-axis spindle 10 via an air bearing 23 formed by an air pad 24. The air bearing 23 is configured by providing the air pad 24 to the tube opening of the guide tube 22 and expelling a jet of air from the air pad 24 onto a sliding surface (exterior surface) of the Z-axis spindle 10.

A top end of a support shaft 28 is supported on a support column 25 provided upright in the guide tube 22. The support column 25 includes a crossbeam 26 at a height at least a displacement amount of the Z-axis spindle 10 away from the guide tube 22. An aperture is provided at an intersection of the crossbeam 26 and a displacement axis of the Z-axis spindle 10. The top end of the support shaft 28 is inserted through the aperture in the crossbeam 26 and includes a flange 30 having a surface orthogonal to the support shaft 28. A ball 31 is provided on a top surface of the flange 30 and configures a bearing with a bearing piece 27 on the support column 25. The top end of the support shaft 28 is thus supported in a manner capable of oscillation.

A drive roller 15 and a driven roller 16 are provided so as to sandwich the support shaft 28 therebetween. The drive roller 15 and the driven roller 16 sandwich the support shaft 28 with a predetermined pressing strength. Thereby, a configuration is achieved in which the drive roller 15 and the driven roller 16 do not idle against the support shaft 28 due to a friction force arising between the support shaft 28 and the drive roller 15 and the driven roller 16. The drive roller 15 revolves by receiving power from a motor (not illustrated), however a detailed description thereof is omitted.

A cylinder 20 is provided along the vertical direction of the Z-axis spindle 10 on the interior of the Z-axis spindle 10. A piston 29 is slidably housed within the cylinder 20. An upper region in a space inside the cylinder 20 demarcated by the piston 29 (i.e., a region on the support shaft 28 side) is a push-up power generating chamber 21. The push-up power generating chamber 21 includes an air jet aperture (not illustrated) supplying air to an interior of the push-up power generating chamber 21. Air is supplied to the push-up power generating chamber 21 such that internal pressure of the push-up power generating chamber 21 has a pressure force sufficient to generate push-up power commensurate with a weight of the Z-axis spindle 10.

A protective tube 41 is provided on an exterior of the cylinder 20, covering an exterior surface of the cylinder 20. The protective tube 41 has a tubular shape of a size to allow a slight gap between the protective tube 41 and the exterior surface of the cylinder 20. A top end of the protective tube 41 is coupled and fixated to the Z-axis spindle 10. A guide path 43 is formed on an upper portion of the Z-axis spindle 10, the guide path 43 guiding a cable 13A from the probe 13 to an extraction outlet 42 formed on a top end of the Z-axis spindle 10 in order to extract the cable 13A. The guide path 43 is formed in the gap between the exterior surface of the protective tube 41 and the interior surface of the Z-axis spindle 10 to allow passage of the cable 13A from the probe 13. The cable 13A is flexible and is guided from the probe 13, through the guide path 43 and the extraction outlet 42, to an exterior of the Z-axis spindle 10 without touching the cylinder 20.

After being extracted from the extraction outlet 42 at the top end of the Z-axis spindle 10 to the exterior of the Z-axis spindle 10, the cable 13A snakes a predetermined distance

within a housing 32. A bent portion 132 is thus created in the cable 13A. Moreover, the cable 13A is then inserted within the X beam 7 and connected to a predetermined circuit.

In the coordinate measuring device 101, the work piece is first placed on the table 1 in order to measure at least one of the position and coordinates of the work piece. Next, the probe 13 is displaced by the X-direction drive mechanism 2, the Y-direction drive mechanism 3, and the Z-direction drive mechanism 4 to bring the probe 13 into contact with the work piece. By recording the position of the probe 13, at least one of the position and the coordinates of the work piece can be measured.

When the Z-direction drive mechanism 4 is driven, the drive roller 15 is rotated. The support shaft 28 is between the drive roller 15 and the driven roller 16, and therefore the drive roller 15 and the driven roller 16 are displaced along the support shaft 28 by the force of friction. When the drive roller 15 and the driven roller 16 are displaced, the Z-axis spindle 10 is guided by the guide tube 22 while being raised and lowered in the vertical direction. As a result, the probe 13 can be raised and lowered in the vertical direction.

When the probe 13 is raised and lowered in the vertical direction, the cable 13A extracted to the exterior of the Z-axis spindle 10 has flexibility, and therefore the bent portion 132 also displaces vertically. In other words, repeating measurement repeats the vertical movement of the bent portion 132. As a result, a conductive wire inside the cable 13A is repeatedly deformed and impedance increases.

FIG. 3 is a block diagram schematically illustrating the configuration of the shape measuring instrument 100 according to Embodiment 1. In order to simplify the drawing, FIG. 3 shows only the X-direction drive mechanism 2, the Y-direction drive mechanism 3, the Z-direction drive mechanism 4, and the probe 13 of the coordinate measuring device 101. The probe 13 includes a calculator 131. The calculator 131 is capable of outputting a signal in response to a signal input from an exterior of the probe 13.

The probe interface 110 includes an impedance detector 111, a measurement controller 115, and a manipulator 118. The impedance detector 111 performs a test operation for impedance in a cable of the coordinate measuring device 101.

The impedance detector 111 includes a calculator 112, a counter 113, and a memory 114. The calculator 112 controls the test operation for impedance in the cable of the coordinate measuring device 101 according to a command of the host computer 120. The counter 113 keeps a count of a value according to a command of the calculator 112. The memory 114 stores information regarding the test operation for impedance in the cable of the coordinate measuring device 101 and is configured so as to be capable of executing data read/write with the calculator 112. The memory 114 can employ an HDD, for example.

The measurement controller 115 includes a drive controller 116 and a signal detector 117. The drive controller 116 controls the X-direction drive mechanism 2, the Y-direction drive mechanism 3, and the Z-direction drive mechanism 4 (displacement mechanisms) based on a drive command signal input when the manipulator 118 is operated or on a drive command signal input from the host computer 120. In addition, the drive controller 116 outputs an operation signal to the host computer 120 when the manipulator 118 is operated.

The signal detector 117 detects the signal output from the probe 13 and through the cable 13A, then detects and outputs to the host computer 120 a displacement amount of the displacement mechanism.

The manipulator **118** is configured by a joystick, for example, and the probe **13** can be manually displaced by operating the manipulator **118**.

The host computer **120** includes a calculator **121**, a memory **122**, an inputter **123**, and an outputter **124**. The calculator **121** is configured with a CPU (Central Processing Unit) or the like and, by providing a predetermined command to the probe interface **110**, controls operations of the coordinate measuring device **101**. Thereby, a test operation for impedance in the cable or a measurement operation measuring the shape of the work piece by displacing the probe **13** along the surface of the work piece with the displacement mechanism can be performed.

The memory **122** stores a program controlling a shape measurement operation of the coordinate measuring device **101**, a program controlling the test operation for impedance in the cable, and the like. The memory **122** is configured so as to be capable of executing data read/write with the calculator **121**. The memory **122** can employ an HDD, for example.

The inputter **123** is configured with a keyboard, a CD-ROM drive, and the like, for example. Via the inputter **123**, a command can be given to the calculator **121** and information can be written to the memory **122**. The outputter **124** is configured with a monitor, for example, and can display results of a shape measurement and a test operation according to a command of the calculator **121**.

Next, a configuration of the calculator **112** is described. FIG. **4** is a block diagram schematically illustrating the configuration of the calculator **112**. The calculator **112** includes a count value controller **112a**, a test data outputter **112b**, a signal reception verifier **112c**, an addition value calculator **112d**, and an addition value determiner **112e**.

The count value controller **112a** controls a counting operation of the counter **113**. The test data outputter **112b** outputs high-speed test data TH to the calculator **131** of the probe **13**. The signal reception verifier **112c** confirms whether a reception confirmation signal Sd output from the calculator **131** of the probe **13** has been received. The addition value calculator **112d** calculates an addition value M based on a value showing test results stored in a memory. The addition value determiner **112e** compares the addition value M and a reception count determination value Mth.

Next, a description is given of the test operation for impedance in the cable of the coordinate measuring device according to the present embodiment. FIG. **5** is a flow chart illustrating the test operation for impedance in the cable of the shape measuring instrument **100** according to Embodiment 1.

First, before beginning measurement with the coordinate measuring device **101**, the host computer **120** issues a command to the calculator **112** of the probe interface **110** to execute a test operation (step S101).

The count value controller **112a** resets a count value i of the counter **113** to "0" (step S102).

The test data outputter **112b** transfers the high-speed test data TH to the calculator **131** of the probe **13** (step S103).

When the high-speed test data TH is received normally, the calculator **131** of the probe **13** transmits the reception confirmation signal Sd to the signal reception verifier **112c** of the probe interface **110** (step S104). Meanwhile, when the high-speed test data TH cannot be received normally, the reception confirmation signal Sd is not transmitted from the calculator **131** of the probe **13**.

The signal reception verifier **112c** confirms whether the reception confirmation signal Sd is received (step S105). For example, the signal reception verifier **112c** waits a predeter-

mined amount of time after transmission of the high-speed test data TH, then determines whether the reception confirmation signal Sd is received.

When the reception confirmation signal Sd has been received, the signal reception verifier **112c** stores information for "1" in the memory **114**, indicating successful reception (step S106). When the reception confirmation signal Sd is not received, the signal reception verifier **112c** stores information for "0" in the memory **114**, indicating failed reception (step S107).

The count value controller **112a** determines whether the value i defined by the counter is equal to a test data transmission count definition value N (where N is any integer equal to or greater than 1) (step S108).

When $i \neq N$, the counter **113** adds 1 to i according to a command from the count value controller **112a** (step S109).

When $i = N$, the addition value calculator **112d** adds the value stored in the memory **114** and calculates the addition value M according to a command from the count value controller **112a** (step S110). Thereby, the calculator **112** identifies a number of times reception was determined to be successful in step S106.

The addition value determiner **112e** compares the addition value M and the reception count determination value Mth (step S111). The reception count determination value Mth is an integer satisfying the expression $1 \leq Mth \leq N$ and is a value expressing a required number of times that reception is possible in order to determine that there is no increase in impedance. The reception count determination value Mth is stored in the memory **114** and can be read by the addition value determiner **112e** when appropriate, for example.

When $M \geq Mth$, transmission of the high-speed test data TH is treated as being in a state where normal transmission is possible and the addition value determiner **112e** outputs a pass determination (step S112). When $M < Mth$, transmission of the high-speed test data TH is treated as being in a state where normal transmission is not possible (i.e., impedance in the cable is treated as increased), and the addition value determiner **112e** outputs a fail determination (step S113).

The addition value determiner **112e** outputs the pass determination and the fail determination noted above to the host computer **120**. When the fail determination is received, the host computer **120** displays an alarm on an output device recommending that the cable be replaced.

Given the above, according to the above-noted configuration and method, increased impedance can be detected in a cable repeatedly bent by repeated measurements that use the coordinate measuring device. Moreover, setting a communication speed of the high-speed test data TH noted above to be higher than a communication speed during shape measurement enables a test in which a margin is maintained with respect to the communication speed during shape measurement. In other words, by performing a test under stricter conditions than those of the shape measurement, the cable can be replaced before the increased impedance affects the shape measurement. In addition, when the communication speed of the shape measurement is 140 Mbps, the communication speed of the high-speed test data TH is 160 Mbps, for example.

In the coordinate measuring device, after the cable is replaced, adjustment of position accuracy and the like becomes necessary. Therefore, a corresponding amount of time is required for the work to replace the cable. Thus, unplanned equipment stoppages are caused when the cable is replaced only after the increased impedance in the cable progresses and the shape measurement becomes impossible. However, according to the present configuration, the

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increased impedance is detected and an alarm is given before the shape measurement becomes impossible. Therefore, a planned cable replacement can be performed. Thereby, by incorporating the cable replacement into plans for equipment usage, unexpected equipment stoppages can be prevented and efficient plans for shape measurement can be formulated.

Embodiment 2

Next, a description is given of a shape measuring instrument **200** according to Embodiment 2. FIG. 6 is a block diagram schematically illustrating a configuration of the shape measuring instrument **200** according to Embodiment 2. The shape measuring instrument **200** has an additional cable **13B**, as compared to the shape measuring instrument **100**. The cable **13B** is connected between the probe interface **110** and the probe **13**. The cable **13B** is a cable for performing communication at a lower speed than the cable **13A**. Other configurations of the shape measuring instrument **200** are similar to those of the shape measuring instrument **100** and descriptions thereof are therefore omitted.

Next, a description is given of a test operation for impedance in the cable of the coordinate measuring device according to the present embodiment. Similar to the shape measuring instrument **100**, the shape measuring instrument **200** can perform the test operation for impedance using the high-speed test data TH through the cable **13A**. Moreover, the shape measuring instrument **200** can perform the test operation for impedance using low-speed test data TL through the cable **13B**. FIG. 7 is a flow chart illustrating the test operation for impedance in the cable **13B** of the shape measuring instrument **200** according to Embodiment 2.

Steps **S201** and **S202** in FIG. 7 are similar to steps **S101** and **S102** of FIG. 5, respectively, and descriptions thereof are therefore omitted.

After step **S202**, the test data outputter **112b** transfers the low-speed test data TL to the calculator **131** of the probe **13** (step **S203**).

Subsequent steps **S203** to **S213** in FIG. 7 are similar to steps **S103** to **S113** in FIG. 5, respectively, and descriptions thereof are therefore omitted.

In other words, similar to the cable **13A**, by transmitting the low-speed test data TL through the cable **13B**, the test operation for impedance in the cable **13B** can be executed. Moreover, when the communication speed of a signal propagated through the cable **13B** during the shape measurement is 6 kbps, the communication speed of the low-speed test data TL is 7 kbps, for example.

According to the above configuration, even when a plurality of cables having different communication speeds are included, the test operation for impedance can be performed on each of the cables. Moreover, in the present embodiment, a situation was described having two cables, **13A** and **13B**; however, a number of cables may of course be three or any other number desired.

Embodiment 3

Next, a description is given of a shape measuring instrument **300** according to Embodiment 3. FIG. 8 is a block diagram schematically illustrating a configuration of the shape measuring instrument **300** according to Embodiment 3. The shape measuring instrument **300** has additional cables **13C** and **13D**, as compared to the shape measuring instrument **100**. The cables **13C** and **13D** are connected between the probe interface **110** and the probe **13**. The cables **13C** and **13D** are short-circuited on the interior of the probe **13**.

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In addition, the cables **13A**, **13C**, and **13D** are gathered together as a single bundled cable **130**. Accordingly, the cables **13A**, **13C**, and **13D** travel along the same pathway, and thus are repeatedly bent the same number of times and to the same degree by repeated shape measurements.

Next, a description is given of the test operation for impedance in the cable of the coordinate measuring device of the present embodiment. Using the cables **13C** and **13D**, the shape measuring instrument **300** can perform the test operation for impedance using the high-speed test data TH. FIG. 9 is a flow chart illustrating the test operation for impedance in the cables of the shape measuring instrument **300** according to Embodiment 3.

Steps **S301** and **S302** in FIG. 9 are similar to steps **S101** and **S102** in FIG. 5, respectively, and descriptions thereof are therefore omitted.

After step **S302**, the test data outputter **112b** transfers the high-speed test data TH to the probe **13** of the coordinate measuring device **101** through the cable **13C** (step **S303**).

The cables **13C** and **13D** are short-circuited on the interior of the probe **13**, and therefore the high-speed test data TH is bounced back, propagated through the cable **13D**, then returns to the probe interface **110** (step **S304**). In other words, the high-speed test data TH is transmitted to the probe interface **110** as the reception confirmation signal Sd shown in FIG. 3. At this point, when the impedance in at least one of the cables **13C** and **13D** is large, the high-speed test data TH is unable to return to the probe interface **110** in a normal state.

The signal reception verifier **112c** confirms whether the high-speed test data TH was received normally (step **S305**). For example, the signal reception verifier **112c** waits a predetermined amount of time after transmission of the high-speed test data TH, then determines whether the high-speed test data TH is received normally.

When the high-speed test data TH is received normally, the signal reception verifier **112c** stores information for "1" in the memory **114**, indicating successful reception (step **S306**). When the high-speed test data TH is not received normally, the signal reception verifier **112c** stores information for "0" in the memory **114**, indicating failed reception (step **S307**).

Subsequent steps **S308** to **S311** in FIG. 9 are similar to steps **S108** to **S111** in FIG. 5, respectively, and descriptions thereof are therefore omitted.

After step **S311**, when $M \geq M_{th}$, transmission of the high-speed test data TH is determined to be in a state where normal transmission is possible. In addition, the test results using the cables **13C** and **13D** are treated as identical to the test results of the cable **13A**, and the addition value determiner **112e** outputs a pass determination (step **S312**). When $M < M_{th}$, transmission of the high-speed test data TH is determined to be in a state where normal transmission is not possible (i.e., impedance in the cables is treated as increased), and the test results using the cables **13C** and **13D** are treated as identical to the test results of the cable **13A**, and the addition value determiner **112e** outputs a fail determination (step **S313**).

As noted above, the cables **13A**, **13C**, and **13D** travel along the same pathway, and thus are repeatedly bent the same number of times and to the same degree by repeated shape measurements. Accordingly, with the present configuration, by performing the test operation for impedance using the cables **13C** and **13D**, the increased impedance in the cable **13A** can be indirectly estimated, the cable **13A** being used in communication of data during the shape measurement. Thus, the shape measuring instrument **300** can perform the same test operation for impedance in the cable as the shape measuring instrument **100**.

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Moreover, as compared to the shape measuring instrument **100**, the shape measuring instrument **300** can omit the calculator **131** of the probe **13**. Thus, the shape measuring instrument **300** contributes to reduced size and cost of probes.

Embodiment 4

Next, a description is given of a shape measuring instrument **400** according to Embodiment 4. The shape measuring instrument **400** is a modification of the shape measuring instrument **100** according to Embodiment 1. The shape measuring instrument **400** performs the test operation for impedance in sequential cables not only before beginning measurement, but also during a probe displacement operation during the shape measurement. FIG. **10** illustrates an operation mode of the shape measuring instrument **400** according to Embodiment 4 during shape measurement.

Prior to beginning the shape measurement (time stamp t1 in FIG. **10**), the shape measuring instrument **400** executes the test operation for impedance in the cables (time stamp t0 in FIG. **10**), similar to the shape measuring instrument **100**. Thereafter, when the shape measurement begins, a measurement mode **401** and a displacement mode **402** are repeated. In the measurement mode **401**, the probe is displaced to actually follow the shape of the work piece to perform the measurement. In the displacement mode **402**, the probe is displaced between measurement locations without performing the shape measurement. The shape measuring instrument **400** performs the test operation for impedance in sequential cables during the displacement mode **402** (time stamps t2 to t4 in FIG. **10**).

According to the present configuration, increased impedance in sequential cables can be observed not only before beginning the shape measurement but also during the shape measurement. Accordingly, the shape measuring instrument **400** can ensure reliability of the shape measurement as compared to the shape measuring instrument **100**.

Moreover, the present invention is not limited to the embodiment described above, and may be modified as needed without departing from the scope of the present invention. For example, the test operation for impedance in the cables using the low-speed test data TL according to the shape measuring instrument **200** can, of course, be applied to the shape measuring instruments **300** or **400**.

For example, the test operation for impedance in the cables during the displacement mode **402** according to the shape measuring instrument **400** can, of course, be executed in the shape measuring instrument **300** as well.

The above-described embodiments described shape measuring instruments; however, such descriptions are exemplary. Accordingly, the present invention can be applied to measurement devices other than shape measuring instruments, or to devices other than measurement devices, such as industrial machinery and equipment having a movable portion with a bent portion and which displace the bent portion according to displacement of the movable portion.

It is noted that the foregoing examples have been provided merely for the purpose of explanation and are in no way to be construed as limiting of the present invention. While the present invention has been described with reference to exemplary embodiments, it is understood that the words which have been used herein are words of description and illustration, rather than words of limitation. Changes may be made, within the purview of the appended claims, as presently stated and as amended, without departing from the scope and spirit of the present invention in its aspects. Although the present invention has been described herein with reference to particular structures, materials and embodiments, the present inven-

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tion is not intended to be limited to the particulars disclosed herein; rather, the present invention extends to all functionally equivalent structures, methods and uses, such as are within the scope of the appended claims.

The present invention is not limited to the above described embodiments, and various variations and modifications may be possible without departing from the scope of the present invention.

What is claimed is:

1. A shape measuring instrument comprising:
 - a measurer having a movable detector configured to detect a shape of a measured object and further configured to output a signal indicating results of the shape detection;
 - a controller configured to receive the signal indicating the results of the shape detection; and
 - a cable configured to transmit the signal indicating the results of the shape detection between the movable detector and the controller, and further configured to bend in accordance with displacement of the movable detector, wherein:
 - the controller comprises an impedance detector configured to detect impedance in the cable, the impedance detector comprising a calculator configured to detect the impedance in the cable according to whether a reception confirmation signal is received through the cable, the reception confirmation signal being output from the movable detector when test data is transmitted through the cable to the movable detector and the movable detector receives the test data.
2. The shape measuring instrument according to claim 1, wherein the calculator is further configured to:
 - output the test data to the movable detector N times (where N is an integer equal to or greater than 1);
 - output a pass determination when the reception confirmation signal is received at least M times (where M is an integer equal to or greater than 1 and equal to or less than N); and
 - output a fail determination when the reception confirmation signal is received less than M times (where M is an integer equal to or greater than 1 and equal to or less than N).
3. The shape measuring instrument according to claim 2, wherein the impedance detector further comprises:
 - a counter configured to control a number of times the test data output from the calculator is output; and
 - a memory configured to store information indicating a number of times the reception confirmation signal output from the calculator is received.
4. The shape measuring instrument according to claim 3, wherein the calculator comprises:
 - a test data outputter configured to output the test data to the movable detector;
 - a signal reception verifier configured to confirm whether the reception confirmation signal is received;
 - a count value controller configured to control a value defined by the counter;
 - a reception calculator configured to calculate the number of times the reception confirmation signal is received; and
 - a determiner configured to determine whether the number of times the reception confirmation signal is received is equal to or greater than M based on the information stored in the memory.
5. The shape measuring instrument according to claim 1, wherein a communication speed of the test data transmitted from the controller, through the cable, and to the movable detector is faster than a communication speed of a signal transmitted from the movable detector, through the cable, and to the controller when performing a shape measurement.

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6. The shape measuring instrument according to claim 1, wherein:

the cable comprises a plurality of cables,
the communication speed of the signal indicating the results of the shape detection transmitted from the movable detector, through the plurality of cables, and to the calculator differs for each of the plurality of cables, and the communication speed of the test data transmitted from the calculator, through the plurality of cables, and to the movable detector differs for each of the plurality of cables.

7. The shape measuring instrument according to claim 1, wherein:

the cable comprises a bundled cable including first through third cables,
the signal indicating the results of the shape detection is transmitted from the movable detector, through the first cable, and to the calculator,
the test data is transmitted from the calculator, through the second cable, and to the movable detector,
a connection end of the second cable on the movable detector side and a connection end of the third cable on the movable detector side are short-circuited,
the test data is transmitted from the movable detector, through the second cable, and to the calculator as the reception confirmation signal, and
impedance detection results for the second and third cables are output as impedance results for the first cable.

8. The shape measuring instrument according to claim 1, wherein the calculator is configured to detect the impedance in the cable before the measurer begins a shape measurement operation.

9. The shape measuring instrument according to claim 8, wherein the calculator is configured to detect the impedance in the cable after the measurer begins the shape measurement operation, during a time when the movable detector is displaced from a first measurement position to a second measurement position without performing shape measurement.

10. An impedance detector comprising:

a calculator configured to output test data through a cable to a movable portion of an instrument having the movable portion, the movable portion configured to output a signal indicating results of an operation, wherein:

the cable is configured to bend in accordance with displacement of the movable portion,
the calculator is configured to detect impedance in the cable according to whether a reception confirmation signal output when the movable portion receives the test data is confirmed to be received through the cable.

11. The impedance detector according to claim 10, wherein the calculator is configured to:

output the test data to the movable portion N times (where N is an integer equal to or greater than 1)

output a pass determination when the reception confirmation signal is received at least M times (where M is an integer equal to or greater than 1 and equal to or less than N), and

output a fail determination when the reception confirmation signal is received less than M times (where M is an integer equal to or greater than 1 and equal to or less than N).

12. The impedance detector according to claim 11, wherein the impedance detector further comprises:

a counter configured to control a number of times the test data output from the calculator is output; and

a memory configured to store information indicating a number of times the reception confirmation signal output from the calculator is received.

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13. The impedance detector according to claim 12, wherein the calculator comprises:

a test data outputter configured to output the test data to the movable portion;

a signal reception verifier configured to confirm whether the reception confirmation signal is received;

a count value controller configured to control a value defined by the counter;

a reception calculator configured to calculate a number of times the reception confirmation signal is received; and

a determiner configured to determine whether the number of times the reception confirmation signal is received is equal to or greater than M based on the information stored in the memory.

14. The impedance detector according to claim 10, wherein a communication speed of the test data transmitted from the calculator, through the cable, and to the movable portion is faster than a communication speed of the signal indicating the results of the operation and transmitted from the movable portion, through the cable, and to the controller of the instrument having the movable portion.

15. The impedance detector according to claim 10, wherein:

the cable comprises a plurality of cables,

the communication speed of the signal indicating the results of the operation and transmitted from the movable portion, through the plurality of cables, and to the controller of the instrument having the movable portion differs for each of the plurality of cables, and

the communication speed of the test data transmitted from the controller, through the plurality of cables, and to the movable portion differs for each of the plurality of cables.

16. The impedance detector according to claim 10, wherein the cable comprises a bundled cable including first through third cables,

the signal indicating results of shape detection is transmitted from the movable portion, through the first cable, and to the calculator,

the test data is transmitted from the calculator, through the second cable, and to the movable portion,

a connection end of the second cable on the movable portion side and a connection end of the third cable on the movable portion side are short-circuited,

the test data is transmitted from the movable portion, through the second cable, and to the calculator as the reception confirmation signal, and

impedance detection results for the second and third cables are output as impedance results for the first cable.

17. The impedance detector according to claim 10, wherein the calculator is configured to detect the impedance in the cable before the movable portion begins an operation outputting the signal indicating the results of the operation.

18. The impedance detector according to claim 17, wherein the calculator is configured to detect the impedance in the cable after the movable portion begins the operation outputting the signal indicating the results of the operation, during a time when the movable portion is displaced from a first measurement position to a second measurement position without outputting the signal indicating the results of the operation.

19. An impedance detection method comprising:

outputting test data through a cable to a movable portion of an instrument having the movable portion, the movable portion outputting a signal indicating results of an operation and the cable being bent in accordance with displacement of the movable portion;

confirming whether a reception confirmation signal is received, the signal being output when the movable portion receives the test data; and

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detecting impedance in the cable according to a result of the confirmation.

20. The impedance detection method according to claim 19 comprising:

outputting the test data to the movable portion N times (where N is an integer equal to or greater than 1);
 outputting a pass determination when the reception confirmation signal is received at least M times (where M is an integer equal to or greater than 1 and equal to or less than N); and
 outputting a fail determination when the reception confirmation signal is received less than M times (where M is an integer equal to or greater than 1 and equal to or less than N).

21. The impedance detection method according to claim 19, wherein a communication speed of the test data transmitted through the cable to the movable portion is faster than a communication speed of the signal indicating the results of the operation and transmitted from the movable portion through the cable.

22. The impedance detection method according to claim 19, wherein:

the cable is a plurality of cables,
 the communication speed of the signal indicating the results of the operation and transmitted from the movable portion through the plurality of cables differs for each of the plurality of cables, and
 the communication speed of the test data transmitted through the plurality of cables to the movable portion differs for each of the plurality of cables.

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23. The impedance detection method according to claim 19, wherein:

the cable is a bundled cable including first through third cables,

a signal indicating results of shape detection is transmitted from the movable portion through the first cable,
 the test data is transmitted through the second cable to the movable portion,

a connection end of the second cable on the movable portion side and a connection end of the third cable on the movable portion side are short-circuited,

the test data is transmitted from the movable portion through the second cable as the reception confirmation signal, and

impedance detection results for the second and third cables are output as impedance results for the first cable.

24. The impedance detection method according to claim 19, wherein the impedance in the cable is detected before the movable portion begins an operation outputting the signal indicating the results of the operation.

25. The impedance detection method according to claim 24, wherein the impedance in the cable is detected after the movable portion begins the operation outputting the signal indicating the results of the operation, during a time when the movable portion is displaced from a first measurement position to a second measurement position without outputting the signal indicating the results of the operation.

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